



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> :		(11) International Publication Number:	WO 95/04151
C12N 15/62, 15/31, 15/54, 1/21, A61K 38/45		A2	(43) International Publication Date: 9 February 1995 (09.02.95)
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(22) International Filing Date: 29 July 1994 (29.07.94)		(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD).	
(30) Priority Data: PCT/GB93/01617 30 July 1993 (30.07.93) WO (34) Countries for which the regional or international application was filed: GB et al. 9401787.8 31 January 1994 (31.01.94) GB		(71) Applicant (for all designated States except US): MEDEVA HOLDINGS B.V. [NL/NL]; Churchill-Laan 223, NL-1078 ED Amsterdam (NL).	
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(54) Title: VACCINE COMPOSITIONS			
(57) Abstract			
<p>The invention provides a DNA construct comprising a DNA sequence encoding a fusion protein of the formula: TetC-(Z)<sub>a</sub>-Het, wherein: TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein, Z is an amino acid, and <sub>a</sub> is zero or a positive integer, provided that (Z)<sub>a</sub> does not include the sequence Gly-Pro. The invention also provides replicable expression vectors containing the constructs, bacteria transformed with the constructs, the fusion proteins <i>per se</i> and vaccine compositions formed from the fusion proteins or attenuated bacteria expressing the fusion proteins.</p>			

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## VACCINE COMPOSITIONS

This invention relates to DNA constructs, replicable expression vectors containing the constructs, bacteria containing the constructs and vaccines containing the bacteria or fusion proteins expressed therefrom. More particularly, the invention relates to novel DNA constructs encoding the C-fragment of tetanus toxin, and to fusion proteins containing tetanus toxin C-fragment.

It is known to prepare DNA constructs encoding two or more heterologous proteins with a view to expressing the proteins in a suitable host as a single fusion protein. However, it has often been found that fusing two proteins together in this way leads to an incorrectly folded chimaeric protein which no longer retains the properties of the individual components. For example, the B-subunits of the Vibrio cholerae (CT-B) and E. coli (LT-B) enterotoxins are powerful mucosal immunogens but genetic fusions to these subunits can alter the structure and properties of the carriers and hence their immunogenicity (see M. Sandkvist et al. J. Bacteriol. 169, pp4570-6, 1987, Clements et al. 1990 and M. Lipscombe et al. Mol. Microbiol. 5, pp 1385, 1990). Moreover, many heterologous proteins expressed in bacteria are not produced in soluble

properly folded or active forms and tend to accumulate as insoluble aggregates (see C. Schein et al. Bio/Technology 6, pp 291-4, 1988 and R. Halenbeck et al. Bio/Technology 7, pp 710-5, 1989.

In our earlier unpublished international patent application PCT/GB93/01617, it is disclosed that by providing a DNA sequence encoding tetanus toxin C-fragment (TetC) linked via a "hinge region" to a second sequence encoding an antigen, the expression of the sequence in bacterial cells is enhanced relative to constructs wherein the C-fragment is absent. For example, the expression level of the full length P28 glutathione S-transferase protein of S. mansoni when expressed as a fusion to TetC from the nirB promoter was greater than when the P28 protein was expressed alone from the nirB promoter. The TetC fusion to the full length P28 protein of S. mansoni was soluble and expressed in both E. coli and S. typhimurium. In addition, the TetC-P28 fusion protein was capable of being affinity purified by a glutathione agarose matrix, suggesting that the P28 had folded correctly to adopt a conformation still capable of binding to its natural substrate. It was previously considered that a hinge region, which typically is a sequence encoding a high proportion of proline and/or glycine amino acids, is essential for promoting the independent folding of both the TetC and the antigenic protein fused thereto. However, it has now been discovered, surprisingly in view of the previous studies on CT-B and LT-B referred to above, that

when the hinge region is omitted between the TetC and a second antigen such as P28, the proteins making up the fusion do exhibit correct folding as evidenced by affinity purification on a glutathione agarose matrix.

Accordingly, in a first aspect, the invention provides a DNA construct comprising a DNA sequence encoding a fusion protein of the formula  $\text{TetC-(Z)}_{\underline{a}}\text{-Het}$ , wherein TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein; Z is an amino acid, and  $\underline{a}$  is zero or a positive integer, provided that  $(Z)_{\underline{a}}$  does not include the sequence Gly-Pro.

Typically  $(Z)_{\underline{a}}$  is a chain of 0 to 15 amino acids, for example 0 to 10, preferably less than 6 and more preferably less than 4 amino acids.

In one embodiment  $(Z)_{\underline{a}}$  is a chain of two or three amino acids, the DNA sequence for which defines a restriction endonuclease cleavage site.

In another embodiment,  $\underline{a}$  is zero.

Usually the group  $(Z)_{\underline{a}}$  will not contain, simultaneously, both glycine and proline, and generally will not contain either glycine or proline at all.

In a further embodiment,  $(Z)_{\underline{a}}$  is a chain of amino acids provided that when  $\underline{a}$  is 6 or more,  $(Z)_{\underline{a}}$  does not contain glycine or proline.

The group  $(Z)_{\underline{a}}$  may be a chain of amino acids substantially devoid of biological activity.

In a second aspect the invention provides a replicable expression vector, for example suitable for use in

bacteria, containing a DNA construct as hereinbefore defined.

In another aspect, the invention provides a host (e.g. a bacterium) containing a DNA construct as hereinbefore defined, the DNA construct being present in the host either in the form of a replicable expression vector such as a plasmid, or being present as part of the host chromosome, or both.

In a further aspect, the invention provides a fusion protein of the form TetC-(Z)<sub>3</sub>-Het as hereinbefore defined, preferably in substantially pure form, said fusion protein being expressible by a replicable expression vector as hereinbefore defined.

In a further aspect the invention provides a process for the preparation of a bacterium (preferably an attenuated bacterium) which process comprises transforming a bacterium (e.g. an attenuated bacterium) with a DNA construct as hereinbefore defined.

The invention also provides a vaccine composition comprising an attenuated bacterium, or a fusion protein, as hereinbefore defined, and a pharmaceutically acceptable carrier.

The heterologous protein "Het" may for example be a heterologous antigenic sequence, e.g. an antigenic sequence derived from a virus, bacterium, fungus, yeast or parasite.

Examples of viral antigenic sequences are sequences derived from a type of human immunodeficiency virus (HIV) such as HIV-1 or HIV-2, the CD4 receptor binding site from

HIV, for example from HIV-1 or -2., hepatitis A, B or C virus, human rhinovirus such as type 2 or type 14, Herpes simplex virus, poliovirus type 2 or 3, foot-and-mouth disease virus (FMDV), rabies virus, rotavirus, influenza virus, coxsackie virus, human papilloma virus (HPV), for example the type 16 papilloma virus, the E7 protein thereof, and fragments containing the E7 protein or its epitopes; and simian immunodeficiency virus (SIV).

Examples of antigens derived from bacteria are those derived from Bordetella pertussis (e.g. P69 protein and filamentous haemagglutinin (FHA) antigens), Vibrio cholerae, Bacillus anthracis, and E.coli antigens such as E.coli heat Labile toxin B subunit (LT-B), E.coli K88 antigens, and enterotoxigenic E.coli antigens. Other examples of antigens include the cell surface antigen CD4, Schistosoma mansoni P28 glutathione S-transferase antigens (P28 antigens) and antigens of flukes, mycoplasma, roundworms, tapeworms, Chlamydia trachomatis, and malaria parasites, eg. parasites of the genus plasmodium or babesia, for example Plasmodium falciparum, and peptides encoding immunogenic epitopes from the aforementioned antigens.

Particular antigens include the full length Schistosoma mansoni P28, and oligomers (e.g. 2, 4 and 8-mers) of the immunogenic P28 aa 115-131 peptide (which contains both a B and T cell epitope), and human papilloma virus E7 protein, Herpes simplex antigens, foot and mouth disease virus antigens and simian immunodeficiency virus

antigens.

The DNA constructs of the present invention may contain a promoter whose activity is induced in response to a change in the surrounding environment. An example of such a promoter sequence is one which has activity which is induced by anaerobic conditions. A particular example of such a promoter sequence is the nirB promoter which has been described, for example in International Patent Application PCT/GB92/00387. The nirB promoter has been isolated from E.coli, where it directs expression of an operon which includes the nitrite reductase gene nirB (Jayaraman et al, J. Mol. Biol. 196, 781-788, 1987), and nirD, nirC, cysG (Peakman et al, Eur. J. Biochem. 191, 315323, 1990). It is regulated both by nitrite and by changes in the oxygen tension of the environment, becoming active when deprived of oxygen, (Cole, Biochem, Biophys. Acta. 162, 356-368, 1968). Response to anaerobiosis is mediated through the protein FNR, acting as a transcriptional activator, in a mechanism common to many anaerobic respiratory genes. By deletion and mutational analysis the part of the promoter which responds solely to anaerobiosis has been isolated and by comparison with other anaerobically regulated promoters a consensus FNR-binding site has been identified (Bell et al, Nucl, Acids. Res. 17, 3865-3874, 1989; Jayaraman et al, Nucl, Acids, Res. 17, 135-145, 1989). It has also been shown that the distance between the putative FNR-binding site and the -10 homology region is critical (Bell et al, Molec. Microbiol.4, 1753-

1763, 1990). It is therefore preferred to use only that part of the nirB promoter which responds solely to anaerobiosis. As used herein, references to the nirB promoter refer to the promoter itself or a part or derivative thereof which is capable of promoting expression of a coding sequence under anaerobic conditions. The preferred sequence, and which contains the nirB promoter is:

AATTCAGGTAAATTCATGTACATCAAATGGTACCCCTTGCTGAATCGTTAAGG  
TAGGCGGTAGGGCC (SEQ ID NO: 1)

In a most preferred aspect, the present invention provides a DNA molecule comprising the nirB promoter operably linked to a DNA sequence encoding a fusion protein as hereinbefore defined.

In another preferred aspect of the invention, there is provided a replicable expression vector, suitable for use in bacteria, containing the nirB promoter sequence operably linked to a DNA sequence encoding a fusion protein as hereinbefore defined.

The DNA molecule or construct may be integrated into the bacterial chromosome, e.g. by methods known per se, and thus in a further aspect, the invention provides a bacterium having in its chromosome, a DNA sequence or construct as hereinbefore defined.

Stable expression of the fusion protein can be obtained in vivo. The fusion protein can be expressed in an attenuated bacterium which can thus be used as a vaccine.

The attenuated bacterium may be selected from the genera Salmonella, Bordetella, Vibrio, Haemophilus, Neisseria and Yersinia. Alternatively, the attenuated bacterium may be an attenuated strain of enterotoxigenic Escherichia coli. In particular the following species can be mentioned: S.typhi - the cause of human typhoid; S.typhimurium - the cause of salmonellosis in several animal species; S.enteritidis - a cause of food poisoning in humans; S.choleraesuis - a cause of salmonellosis in pigs; Bordetella pertussis - the cause of whooping cough; Haemophilus influenzae - a cause of meningitis; Neisseria gonorrhoea the cause of gonorrhoea; and Yersinia - a cause of food poisoning.

Examples of attenuated bacteria are disclosed in, for example EP-A-0322237 and EP-A-0400958, the disclosures in which are incorporated by reference herein.

An attenuated bacterium containing a DNA construct according to the invention, either present in the bacterial chromosome, or in plasmid form, or both, can be used as a vaccine. Fusion proteins (preferably in substantially pure form) expressed by the bacteria can also be used in the preparation of vaccines. For example, a purified TetC-P28 fusion protein in which the TetC protein is linked via its C-terminus to the P28 protein with no intervening hinge region has been found to be immunogenic on its own. In a further aspect therefore, the invention provides a vaccine composition comprising a pharmaceutically acceptable carrier or diluent and, as active ingredient, an attenuated

bacterium or fusion protein as hereinbefore defined.

The vaccine may comprise one or more suitable adjuvants.

The vaccine is advantageously presented in a lyophilised form, for example in a capsular form, for oral administration to a patient. Such capsules may be provided with an enteric coating comprising, for example, Eudragit "S", Eudragit "L", Cellulose acetate, Cellulose acetate phthalate or Hydroxypropylmethyl Cellulose. These capsules may be used as such, or alternatively, the lyophilised material may be reconstituted prior to administration, e.g. as a suspension. Reconstitution is advantageously effected in buffer at a suitable pH to ensure the viability of the organisms. In order to protect the attenuated bacteria and the vaccine from gastric acidity, a sodium bicarbonate preparation is advantageously administered before each administration of the vaccine. Alternatively, the vaccine may be prepared for parenteral administration, intranasal administration or intramammary administration.

The attenuated bacterium containing the DNA construct or fusion protein of the invention may be used in the prophylactic treatment of a host, particularly a human host but also possibly an animal host. An infection caused by a microorganism, especially a pathogen, may therefore be prevented by administering an effective dose of an attenuated bacterium according to the invention. The bacterium then expresses the fusion protein which is

capable of raising antibody to the micro-organism. The dosage employed will be dependent on various factors including the size and weight of the host, the type of vaccine formulated and the nature of the fusion protein.

An attenuated bacterium according to the present invention may be prepared by transforming an attenuated bacterium with a DNA construct as hereinbefore defined. Any suitable transformation technique may be employed, such as electroporation. In this way, an attenuated bacterium capable of expressing a protein or proteins heterologous to the bacterium may be obtained. A culture of the attenuated bacterium may be grown under aerobic conditions. A sufficient amount of the bacterium is thus prepared for formulation as a vaccine, with minimal expression of the fusion protein occurring.

The DNA construct may be a replicable expression vector comprising the nirB promoter operably linked to a DNA sequence encoding the fusion protein. The nirB promoter may be inserted in an expression vector, which already incorporates a gene encoding one of the heterologous proteins (e.g. the tetanus toxin C fragment), in place of the existing promoter controlling expression of the protein. The gene encoding the other heterologous protein (e.g. an antigenic sequence) may then be inserted. The expression vector should, of course, be compatible with the attenuated bacterium into which the vector is to be inserted.

The expression vector is provided with appropriate

transcriptional and translational control elements including, besides the nirB promoter, a transcriptional termination site and translational start and stop codons. An appropriate ribosome binding site is provided. The vector typically comprises an origin of replication and, if desired, a selectable marker gene such as an antibiotic resistance gene. The vector may be a plasmid.

The invention will now be illustrated but not limited, by reference to the following examples and the accompanying drawings, in which:

Figure 1 is a schematic illustration of the construction of plasmid pTECH1;

Figure 2 illustrates schematically the preparation of the plasmid pTECH1-28 from the starting materials pTECH1 and PUC19-P28;

Figure 3 illustrates schematically the preparation of the plasmid pTECH3-P28 from the starting materials plasmids pTECH1-P28 and pTETnir15;

Figures 4 and 5 are western blots obtained from bacterial cells harbouring the pTECH3-P28 construct; and

Figure 6 illustrates the glutathione affinity purification of TetC fusions as determined by SDS-PAGE and Coomassie Blue Staining.

In accordance with the invention a vector was constructed to allow genetic fusions to the C-terminus of the highly immunogenic C fragment of tetanus toxin, without the use of a heterologous hinge domain. A fusion was constructed, with the gene encoding the protective 28kDa

glutathione *S*-transferase from Schistosoma mansoni. The recombinant vector was transformed into *Salmonella typhimurium* (SL338; *rm*<sup>t</sup>). The resulting chimeric protein was stably expressed in a soluble form in *salmonella* as assessed by western blotting with fragment C and glutathione *S*-transferase antisera. Furthermore it was found that the P28 component of the fusion retains the capacity to bind glutathione.

The construction of the vector and the properties of the fusion protein expressed therefrom are described in more detail below.

#### EXAMPLE 1

##### Preparation of pTECH1

The preparation of pTECH1, a plasmid incorporating the nirB promoter and TetC gene, and a DNA sequence encoding a hinge region and containing restriction endonuclease sites to allow insertion of a gene coding for a second or guest protein, is illustrated in Figure 1. Expression plasmid pTETnir15, the starting material shown in Figure 1, was constructed from pTETtac115 (Makoff *et al*, Nucl. Acids Res. 17 10191-10202, 1989); by replacing the EcoRI-ApaI region (1354bp) containing the lacI gene and tac promoter with the following pair of oligos 1 and 2:

Oligo-1 5' AATTCAAGGTAAATTGATGTACATCAAATGGTACCCCTTGCTGAAT  
CGTTAAGGTAGGCGGTAGGGCC-3' (SEQ ID NO: 2)

Oligo-2 3'-GTCCATTAAACTACATGTAGTTACCATGGGAAACGACTTA  
GCAATTCCATCCGCCATC-5' (SEQ ID NO: 3)

The oligonucleotides were synthesised on a Pharmacia Gene Assembler and the resulting plasmids confirmed by sequencing (Makoff *et al*, *Bio/Technology* 7, 1043-1046, 1989).

The pTETnir15 plasmid was then used for construction of the pTECH1 plasmid incorporating a polylinker region suitable as a site for insertion of heterologous DNA to direct the expression of fragment C fusion proteins. pTETnir15 is a known pAT153-based plasmid which directs the expression of fragment C. However, there are no naturally occurring convenient restriction sites present at the 3'-end of the TetC gene. Therefore, target sites, preceded by a hinge region, were introduced at the 3'-end of the TetC coding region by means of primers SEQ ID NO: 4 and SEQ ID NO: 5 tailored with "add-on" adapter sequences (Table 1), using the polymerase chain reaction (PCR) [K. Mullis *et al*, *Cold Spring Harbor Sym. Quant. Biol.* 51, 263-273 1986]. Accordingly, pTETnir15 was used as a template in a PCR reaction using primers corresponding to regions covering the SacII and BamHI sites. The anti-sense primer in this amplification was tailored with a 38 base 5'-adaptor sequence. The anti-sense primer was designed so that a sequence encoding novel XbaI, SpeI and BamHI sites were incorporated into the PCR product. In addition, DNA sequences encoding additional extra amino acids including proline were incorporated (the hinge regions) and a translation stop codon signal in frame with the fragment C open reading frame.

The PCR product was gel-purified and digested with SacII and BamHI, and cloned into the residual 2.8 kb vector pTETnir15 which had previously been digested by SacII and BamHI. The resulting plasmid purified from transformed colonies and named pTECH 1 is shown in Figure 1. Heterologous sequences such as the sequence encoding the Schistosoma mansoni P28 glutathione S-transferase (P28) were cloned into the XbaI SpeI and BamHI sites in accordance with known methods.

The DNA sequence of the plasmid pTECH1 is shown in the sequence listing as SEQ ID NO: 6.

TABLE 1

DNA SEQUENCES OF OLIGONUCLEOTIDES UTILISED IN THE CONSTRUCTION OF THE TETC-HINGE VECTORS

A). Primer 1. Sense PCR (21mer). (SEQ ID NO: 4)

SacII

5'AAA GAC TCC GCG GGC GAA GTT -3'

TETANUS TOXIN C FRAGMENT SEQ.

B). Primer 2. Anti-Sense PCR Primer (64mer). (SEQ ID NO: 5)

BamHI	STOP	SpeI	XbaI	5'---3'
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5' - CTAT GGA TCC TTA ACT AGT GAT TCT AGA GGT ACC TGG GGT  
GTC GTT GGT CCA ACC TTC ATC GGT -3'

TETANUS TOXIN C FRAGMENT SEQ. 3'-END

EXAMPLE 2

Construction of pTECH1-P28

A P28 gene expression cassette was produced by PCR

using pUC19-P28 DNA (a kind gift from Dr R Pierce, Pasteur Institute, Lille) as template. Oligonucleotide primers were designed to amplify the full length P28 gene beginning with the start codon and terminating with the stop codon. In addition, the sense and antisense primers were tailored with the restriction sites for XbaI and BamHI respectively. The primers are shown in the sequence listing as SEQ ID NO: 7 and SEQ ID NO: 8.

The product was gel-purified and digested with XbaI and BamHI and then cloned into pTECH1 which had previously been digested with these enzymes and subsequently gel-purified. The DNA sequence of pTECH1 - P28 is shown in sequence listing as SEQ ID NO: 9.

#### Expression of the TetC-Hinge-P28 fusion protein

Several bacterial strains, namely S. typhimurium strains SL 5338 (A. Brown et al, J.Infect.Dis. 155, 86-92, 1987) and SL3261 and E. coli (TG2) were transformed with pTECH1-P28 by means of electroporation. SL3261 strains harbouring the pTECH1-P28 plasmid have been deposited at the National Collection of Type Cultures, 61 Colindale Avenue, London, NW9 5HT, UK under the accession number NCTC 12833. A strain of SL3261 containing the pTECH1 plasmid has been deposited under accession number NCTC 12831. The identity of recombinants was verified by restriction mapping of the plasmid DNA harboured by the cells. Further expression of the TetC-P28 fusion protein was then evaluated by SDS-PAGE and western blotting of bacterial cells harbouring the construct. It was found that the

fusion protein remains soluble, cross-reacts with antisera to both TetC and P28, and is also of the expected molecular weight, 80kDa, for a full length fusion.

The fusion protein was stably expressed in E.coli (TG2) and S. typhimurium (SL5338,SL3261) as judged by SDS-PAGE and western blotting. Of interest was a band of 50kDa which co-migrates with the TetC-Hinge protein alone and cross-reacts exclusively with the anti-TetC sera is visible in a western blot. As the codon selection in the hinge region has been designed to be suboptimal, the rare codons may cause pauses during translation which may occasionally lead to the premature termination of translation, thus accounting for this band.

#### Affinity purification of the TetC-P28 fusion

Glutathione is the natural substrate for P28, a glutathione S-transferase. The amino acid residues involved in binding glutathione are thought to be spatially separated in the primary structure of the polypeptide and brought together to form a glutathione binding pocket in the tertiary structure (P. Reinemer et al. EMBO, J8, 1997-2005, 1991). In order to gauge whether the P28 component of the fusion has folded correctly to adopt a conformation capable of binding glutathione, its ability to be affinity purified on a glutathione-agarose matrix was tested. The results obtained (not shown) demonstrated that TetC-P28 can indeed bind to the matrix and the binding is reversible, as the fusion can be competitively eluted with free glutathione.

EXAMPLE 3Construction of pTECH3-P28

The plasmid pTECH1-P28 directs the expression of the S. mansoni P28 protein as a C-terminal fusion to fragment C from tetanus toxin separated by a heterologous hinge domain. Expression of the fusion protein is under the control of the nirB promoter. The vector pTECH3-P28 was in part constructed from the plasmid pTETnir15 by the polymerase chain reaction (PCR) using the high fidelity thermostable DNA polymerase from Pyrococcus fusorius, which possesses an associated 3'5' exonuclease proofreading activity. The sequence of steps is summarised in Figure 5. In order to generate a TetC-hingeless replacement cassette, the segment of DNA from the unique SacII site within the TetC gene to the final codon was amplified by means of the PCR reaction, using pTETnir15 as template DNA. The primers used in the PCR amplification are shown in the sequence listing as SEQ ID NO: 10 and SEQ ID NO: 11. The antisense primer in this amplification reaction was tailored with an XbaI recognition sequence.

The amplification reaction was performed according to the manufacturer's instructions (Stratagene, La Jolla, CA, USA). The product was gel-purified, digested with SacII and XbaI, and then cloned into the residual pTECH1-P28 vector which had been previously digested with the respective enzymes SacII and XbaI. The resulting vector was designated pTECH3-P28. The DNA sequence of pTECH3-P28 is shown in the sequence listing as SEQ ID NO: 12.

EXAMPLE 4Transformation of *S. typhimurium* SL5338 (galE r<sup>-</sup>m<sup>+</sup>) with pTECH3-P28, and Analysis of the Transformants

*S. typhimurium* SL5338 (galE r<sup>-</sup>m<sup>+</sup>) were cultured in either L or YT broth and on L-agar with ampicillin (50 g/ml) if appropriate and were transformed with the pTECH3-P28 plasmid. The transformation protocol was based on the method described by MacLachlan and Sanderson. (MacLachlan PR and Sanderson KE, 1985. Transformation of Salmonella typhimurium with plasmid DNA : differences between rough and smooth strains. J. Bacteriology 161, 442-445).

A 1ml overnight culture of *S. typhimurium* SL5338 (r<sup>-</sup>m<sup>+</sup>; Brown A, Hormaeche CE, Demarco de Hormaeche R, Dougan G, Winther M, Maskell D, and Stocker BAD, 1987. J. Infect. Dis. 155, 86-92) was used to inoculate 100 ml of LB broth and shaken at 37°C until the culture reached OD<sub>650</sub> = 0.2. The cells were harvested at 3000 x g and resuspended in 0.5 volumes of ice-cold 0.1M MgCl<sub>2</sub>. The cells were pelleted again and resuspended in 0.5 volumes of ice-cold CaCl<sub>2</sub>. This step was repeated once more and the cells resuspended in 1 ml of 0.1M CaCl<sub>2</sub> to which was added 50  $\mu$ l of TES (50 mM Tris, 10 mM EDTA, 50 mM NaCl, pH 8.0). The cells were incubated on ice for 45 to 90 minutes. To 150 $\mu$ l of cells was added 100ng of plasmid DNA in 1 - 2 $\mu$ l. The mixture was incubated on ice for 30 minutes prior to heat-shock at 42°C for 2 minutes, and immediate reincubation on ice for 1 minute. To the transformed mixture was added 2 ml of LB broth and incubated for 1.5 hours to allow

expression of the ampicillin drug resistance gene, B-lactamase. Following incubation 20  $\mu$ l and 200  $\mu$ l of cells were spread on to LB agar plates containing 50  $\mu$ g/ml of ampicillin. The plates were dried and incubated at 37°C overnight.

The identity of recombinants was verified by restriction mapping of the plasmid DNA and by western blotting with antisera directed against TetC and P28.

#### SDS-PAGE and Western Blotting

Expression of the TetC fusions was tested by SDS-PAGE and western blotting. S. typhimurium SL5338 (galE  $r^m^t$ ) bacterial cells containing the pTECH3-P28 plasmid and growing in mid-log phase, with antibiotic selection, were harvested by centrifugation and the proteins fractionated by 10% SDS-PAGE. The proteins were transferred to a nitrocellulose membrane by electroblotting and reacted with either a polyclonal rabbit antiserum directed against TetC or the full length P28 protein. The blots were then probed with goat anti-rabbit Ig conjugated to horse-radish peroxidase (Dako, High Wycombe, Bucks, UK) and developed with 4-chloro-1-naphthol). The results of the western blotting experiments are shown in Figures 4 and 5; Figure 4 illustrating the results of probing with rabbit anti-TetC polyclonal antiserum and Figure 5 illustrates the results of probing with rabbit anti-P28 polyclonal antiserum. In each case lanes 1, 2 and 3 are independent clones of SL5338 (pTECH3-P28), lanes 4, 5 and 6 are SL5338 (pTECH1-P28) and

lane 7 is SL5338 (pTETnir15). The molecular weight markers are indicated. From the results, it is evident that the fusion protein remains soluble, reacts with antisera to both TetC and P28, and is also of the expected molecular weight, 80 kDa, for a full length fusion (Figure 4). Furthermore the fusion protein appears to be stably expressed.

#### Glutathione-Agarose Affinity Purification

Glutathione is the natural substrate for P28, a glutathione *S*-transferase. The amino acid residues involved in binding glutathione are thought to be spatially separated in the primary structure of the polypeptide and brought together to form a glutathione binding pocket in the tertiary structure. In order to gauge whether the P28 component of the fusion has folded correctly to adopt a conformation capable of binding glutathione, we tested its ability to be affinity purified on a glutathione agarose matrix.

Bacterial cells containing pTECH3-P28 and expressing the TetC full length P28 gene fusion were grown to log phase, chilled on ice, and harvested by centrifugation at 2500 x g for 15 min at 4C. The cells were resuspended in 1/15th the original volume of ice-cold phosphate buffered saline (PBS) and lysed by sonication in a MSE Soniprep 150 (Gallenkamp, Leicester, UK). The insoluble material was removed by centrifugation and to the supernatant was added 1/6 volume of a 50% slurry of pre-swollen glutathione-agarose beads (Sigma, Poole, Dorset, UK). After mixing

gently at room temperature for 1 hour the beads were collected by centrifugation at 1000 x g for 10 secs. The supernatant was discarded and the beads resuspended in 20 volumes of cold PBS-0.5% Triton X100 and the beads collected again by centrifugation. The washing step was repeated three more times. The fusion protein was eluted by adding 1 volume of SDS-PAGE sample buffer. For comparison purposes, a similar procedure was followed with bacterial cells containing the PTECH1-P28 plasmid from which TetC-hinge-P28 fusion protein is expressed. Extracts from clones containing either plasmid were compared using SDS-PAGE and the results are shown in Figure 6. In Figure 6, lanes 1, 2 and 3 are clones of SL5338 (pTECH1-P28) whereas lanes 4, 5 and 6 are independent clones of SL 5338 (pTECH3-P28).

The results suggest that the TetC-P28 fusion protein can indeed bind to the matrix and the binding is reversible regardless of the absence of a heterologous hinge domain (data not shown). It is possible that a peptide sequence present at the C-terminus of TetC may in fact impart flexibility to this particular region.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

## (i) APPLICANT:

- (A) NAME: MEDEVA HOLDINGS BV
- (B) STREET: CHURCHILL-LAAN 223
- (C) CITY: AMSTERDAM
- (E) COUNTRY: THE NETHERLANDS
- (F) POSTAL CODE (ZIP): 1078 ED

## (ii) TITLE OF INVENTION: VACCINES

## (iii) NUMBER OF SEQUENCES: 20

## (iv) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: PatentIn Release #1.0, Version #1.25 (EPO)

## (vi) PRIOR APPLICATION DATA:

- (A) APPLICATION NUMBER: PCT/GB93/01617
- (B) FILING DATE: 30-JUL-1993

## (vi) PRIOR APPLICATION DATA:

- (A) APPLICATION NUMBER: GB 9401787.8
- (B) FILING DATE: 31-JAN-1994

## (2) INFORMATION FOR SEQ ID NO: 1:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 68 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA (genomic)

## (iii) HYPOTHETICAL: NO

## (iii) ANTI-SENSE: NO

## (vi) ORIGINAL SOURCE:

- (A) ORGANISM: Escherichia coli

## (ix) FEATURE:

- (A) NAME/KEY: promoter
- (B) LOCATION: 1..61

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

AATTCAGGTA AATTTGATGT ACATCAAATG GTACCCCTTG CTGAATCGTT AAGGTAGGCG 60  
GTAGGGCC 68

(2) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 68 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

AATTCAGGTA AATTTGATGT ACATCAAATG GTACCCCTTG CTGAATCGTT AAGGTAGGCG 60  
GTAGGGCC 68

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 60 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

GTCCATTAA ACTACATGTA GTTTACCATG GGGAACGACT TAGCAATTCC ATCCGCCATC 60

(2) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

AAAGACTCCG CGGGCGAAGT T

21

(2) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 64 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

CTATGGATCC TTAACCTAGTG ATTCTAGAGG GCCCCGGCCC GTCGTTGGTC CAACCTTCAT

60

CGGT

64

(2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 3754 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: circular

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT	60
AGGGCCAGA TCTTAATCAT CCACAGGAGA CTTTCTGATG AAAAACCTTG ATTGTTGGGT	120
CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGGACAT	180
CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTTATCA CATATCCAGA	240
TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACAA CGAACATCTTC	300
TGAAGTTATC GTGCACAAAGG CCATGGACAT CGAACATCAC GACATGTTCA ACAACTTCAC	360
CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC	420
TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG	480
GTCTGTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG AAAGACTCCG CGGGCGAAGT	540
TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTCAAC GCGTACCTGG CTAACAAATG	600
GGTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT	660
TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC	720
TCTTAAGCTG GACCGTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAAACTG TATACCAGCT ACCTGTCTAT	840
CACCTTCCTG CGTGACTTCT GGGGTAACCC GCTGCGTTAC GACACCGAAT ATTACCTGAT	900
CCCGGTAGCT TCTAGCTCTA AAGACGTTCA GCTGAAAAAC ATCACTGACT ACATGTACCT	960
GACCAACGCG CCGTCCTACA CTAACGGTAA ACTGAACATC TACTACCGAC GTCTGTACAA	1020
CGGCCTGAAA TTCATCATCA AACGCTACAC TCCGAACAAAC GAAATCGATT CTTCTGTTAA	1080
ATCTGGTGAC TTCATCAAAC TGTACGTTTC TTACAACAAAC AACGAACACA TCGTTGGTTA	1140
CCCGAAAGAC GGTAACGCTT TCAACAAACCT GGACAGAATT CTGCGTGTGTTG GTTACAACGC	1200
TCCGGGTATC CCGCTGTACA AAAAAATGGA AGCTGTTAAA CTGCGTGACC TGAAAACCTA	1260
CTCTGTTCAAG CTGAAACTGT ACGACGACAA AAACGCTTCT CTGGGTCTGG TTGGTACCCA	1320
CAACGGTCAG ATCGGTAACG ACCCGAACCG TGACATCCTG ATCGCTTCTA ACTGGTACTT	1380
CAACCACCTG AAAGACAAAAA TCCTGGGTTG CGACTGGTAC TTCGTTCCGA CCGATGAAGG	1440

TTGGACCAAC GACGGGCCGG GGCCCTCTAG AATCACTAGT TAAGGATCCG CTAGCCCGCC	1500
TAATGAGCGG GCTTTTTTTT CTCGGGCAGC GTTGGGTCTT GGCCACGGGT GCGCATGATC	1560
GTGCTCCTGT CGTTGAGGAC CCGGCTAGGC TGGCGGGGTT GCCTTACTGG TTAGCAGAAT	1620
GAATCACCGA TACCGGAGCG AACGTGAAGC GACTGCTGCT GCACAAACGTC TGCGACCTGA	1680
GCAACAAACAT GAATGGTCTT CGGTTCCGT GTTTCGTAAA GTCTGGAAAC GCGGAAGTCA	1740
GCGCTCTTCC GCTTCCTCGC TCACTGACTC GCTGCGCTCG GTCGTTGGC TGCGGCGAGC	1800
GGTATCAGCT CACTCAAAGG CGGTAATACG GTTATCCACA GAATCAGGGG ATAACGCAGG	1860
AAAGAACATG TGAGCAAAAG GCCAGCAAAA GGCCAGGAAC CGTAAAAAGG CCGCGTTGCT	1920
GGCGTTTTTC CATAGGCTCC GCCCCCTGA CGAGGCATCAC AAAAATCGAC GCTCAAGTCA	1980
GAGGTGGCGA AACCCGACAG GACTATAAAG ATACCAGGCG TTTCCCCCTG GAAGCTCCCT	2040
CGTGCCTCT CCTGTTCCGA CCCTGCCGCT TACCGGATAC CTGTCGGCCT TTCTCCCTTC	2100
GGGAAGCGTG GCGCTTTCTC AATGCTCACG CTGTAGGTAT CTCAGTCGG TGTAGGTCTG	2160
TCGCTCCAAG CTGGGCTGTG TGCACGAACC CCCCCTTCAG CCCGACCGCT GCGCCTTATC	2220
CGGTAACATAT CGTCTTGAGT CCAACCCGGT AAGACACGAC TTATGCCAC TGGCAGCAGC	2280
CACTGGTAAC AGGATTAGCA GAGCGAGGTA TGTAGGCGGT GCTACAGAGT TCTTGAAGTG	2340
GTGGCCTAAC TACGGCTACA CTAGAAGGAC AGTATTTGGT ATCTGCGCTC TGCTGAAGCC	2400
AGTTACCTTC GGAAAAAGAG TTGGTAGCTC TTGATCCGGC AAACAAACCA CCGCTGGTAG	2460
CGGTGGTTTT TTTGTTTGCA AGCAGCAGAT TACGCGCAGA AAAAAAGGAT CTCAAGAAGA	2520
TCCTTTGATC TTTCTACGG GGTCTGACGC TCAGTGGAAC GAAAACTCAC GTTAAGGGAT	2580
TTTGGTCATG AGATTATCAA AAAGGATCTT CACCTAGATC CTTTTAAATT AAAAATGAAG	2640
TTTTAAATCA ATCTAAAGTA TATATGAGTA AACCTGGTCT GACAGTTACC AATGCTTAAT	2700
CAGTGAGGCA CCTATCTCAG CGATCTGTCT ATTCGTTCA TCCATAGTTG CCTGACTCCC	2760
CGTCGTGTAG ATAACCTACGA TACGGGAGGG CTTACCATCT GGCCCCAGTG CTGCAATGAT	2820
ACCGCGAGAC CCACGCTCAC CGGCTCCAGA TTTATCAGCA ATAAACCAAGC CAGCCGGAAG	2880
GGCCGAGCGC AGAAGTGGTC CTGCAACTTT ATCCGCCTCC ATCCAGTCTA TTAATTGTTG	2940
CCGGGAAGCT AGAGTAAGTA GTTCGCCAGT TAATAGTTG CGAACGTTG TTGCCATTGC	3000
TGCAGGCATC GTGGTGTAC GCTCGTCGTT TGGTATGGCT TCATTCAAGCT CCGGTTCCCA	3060

ACGATCAAGG CGAGTTACAT GATCCCCAT GTTGTGAAA AAAGCGGTTA GCTCCTTCGG	3120
TCCTCCGATC GTTGTAGAA GTAAGTTGGC CGCAGTGTGTTA TCACTCATGG TTATGGCAGC	3180
ACTGCATAAT TCTCTTACTG TCATGCCATC CGTAAGATGC TTTTCTGTGA CTGGTGAGTA	3240
CTCAACCAAG TCATTCTGAG AATAGTGTAT GCGGCGACCG AGTTGCTCTT GCCCGGCGTC	3300
AACACGGGAT AATACCGCGC CACATAGCAG AACTTTAAAAA GTGCTCATCA TTGGAAAACG	3360
TTCTTCGGGG CGAAAACCTCT CAAGGATCTT ACCGCTGTTG AGATCCAGTT CGATGTAACC	3420
CACTCGTGCA CCCAACTGAT CTTCAGCATC TTTTACTTTT ACCAGCGTTT CTGGGTGAGC	3480
AAAAACAGGA AGGCAAAATG CCGCAAAAAA GGGATAAGG GCGACACGGA AATGTTGAAT	3540
ACTCATACTC TTCCCTTTTC AATATTATTG AAGCATTAT CAGGGTTATT GTCTCATGAG	3600
CGGATACATA TTTGAATGTA TTTAGAAAAA TAAACAAATA GGGGTTCCGC GCACATTTCC	3660
CCGAAAAGTG CCACCTGACG TCTAAGAAC CATTATTATC ATGACATTAA CCTATAAAAAA	3720
TAGGCGTATC ACGAGGCCCT TTCGTCTTCA AGAA	3754

## (2) INFORMATION FOR SEQ ID NO: 7:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

TAGTCTAGAA TGGCTGGCGA GCATATCAAG

30

## (2) INFORMATION FOR SEQ ID NO: 8:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

TTAGGATCCT TAGAAGGGAG TTGCAGGCCT

30

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 4378 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: circular

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT

60

AGGGCCCAGA TCTTAATCAT CCACAGGAGA CTTTCTGATG TET C GENE START CODON AAAAACCTTG ATTGTTGGGT

120

CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGGACAT

180

CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTTATCA CATATCCAGA

240

TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACAA CGGAATCTTC

300

TGAAGTTATC GTGCACAAGG CCATGGACAT CGAATACAAC GACATGTTCA ACAACTTCAC

360

CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC

420

TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG

480

SacII

GTCTGTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG AAAGACTCCG CGGGCGAAGT

540

TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTAAC GCGTACCTGG CTAACAAATG

600

GGTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT

660

TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC

720

TCTTAAGCTG GACCGTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAAACTG TATACCAGCT ACCTGTCTAT	840
CACCTTCCTG CGTGACTTCT GGGGTAACCC GCTGCGTTAC GACACCGAAT ATTACCTGAT	900
CCCGGTAGCT TCTAGCTCTA AAGACGTTCA GCTGAAAAAC ATCACTGACT ACATGTACCT	960
GACCAACGCG CCGCCTACA CTAACGGTAA ACTGAACATC TACTACCGAC GTCTGTACAA	1020
CGGCCTGAAA TTCATCATCA AACGCTACAC TCCGAACAAC GAAATCGATT CTTTCGTTAA	1080
ATCTGGTGAC TTCATCAAAC TGTACGTTTC TTACAACAAC AACGAACACA TCGTTGGTTA	1140
CCCGAAAGAC GGTAAACGCTT TCAACAACCT GGACAGAATT CTGCGTGTG GTTACAACGC	1200
TCCGGGTATC CCGCTGTACA AAAAAATGGA AGCTGTTAAA CTGCGTGACC TGAAAACCTA	1260
CTCTGTTCACTGAAACACTGT ACGACGACAA AAACGCTTCT CTGGGTCTGG TTGGTACCCA	1320
CAACGGTCAG ATCGGTAACG ACCCGAACCG TGACATCCTG ATCGCTTCTA ACTGGTACTT	1380
CAACCACCTG AAAGACAAAAA TCCTGGGTTG CGACTGGTAC TTCGTTCCGA CCGATGAAGG	1440
<b>HINGE DOMAIN XbaI S.Mansoni P28 GENE START</b>	
TTGGACCAAC GAC <u>GGGCCGG</u> <u>GGCCCTCTAG</u> <u>AATGGCTGGC</u> GAGCATATCA AGGTTATCTA	1500
TTTTGACGGA CGCGGACGTG CTGAATCGAT TCGGATGACT CTTGTGGCAG CTGGTGTAGA	1560
CTACGAAGAT GAGAGAATTA GTTTCCAAGA TTGGCCAAAA ATCAAACCAA CTATTCCAGA	1620
CGGACGATTG CCTGCAGTGA AAGTCACTGA TGATCATGGG CACGTGAAAT GGATGTTAGA	1680
GAGTTGGCT ATTGCACGGT ATATGGCGAA GAAACATCAT ATGATGGGTG AAACAGACGA	1740
GGAATACTAT AGTGTGAAA AGTTGATTGG TCATGCTGAA GATGTAGAAC ATGAATATCA	1800
CAAAACTTTG ATGAAGCCAC AAGAAGAGAA AGAGAAGATA ACCAAAGAGA TATTGAACGG	1860
CAAAGTTCCA GTTCTTCTCA ATATGATCTG CGAATCTCTG AAAGGGTCGA CAGGAAAGCT	1920
GGCTGTTGGG GACAAAGTAA CTCTAGCTGA TTTAGTCCTG ATTGCTGTCA TTGATCATGT	1980
GAATGATCTG GATAAAGGAT TTCTAACTGG CAAGTATCCT GAGATCCATA AACATCGAGA	2040
AAATCTGTTA GCCAGTTCAC CGCGTTGGC GAAATATTTA TCGAACAGGC CTGCAACTCC	2100
<b>STOP BamHI</b>	
CTTCTAAGGA TCCGCTAGCC CGCCTAATGA GCGGGCTTTT TTTTCTCGGG CAGCGTTGGG	2160
TCCTGGCCAC GGGTGCACAT GATCGTGCTC CTGTCGTTGA GGACCCGGCT AGGCTGGCGG	2220
GGTTGCCTTA CTGGTTAGCA GAATGAATCA CCGATAACGCG AGCGAACGTG AAGCGACTGC	2280

TGCTGCAAAA CGTCTGCGAC CTGAGCAACA ACATGAATGG TCTTCGGTTT CCGTGTTCG	2340
TAAAGTCTGG AAACGCGGAA GTCAGCGCTC TTCCGCTTCC TCGCTCACTG ACTCGCTGCG	2400
CTCGGTCGTT CGGCTGCGGC GAGCGGTATC AGCTCACTCA AAGGCGGTAA TACGGTTATC	2460
CACAGAATCA GGGGATAACG CAGGAAAGAA CATGTGAGCA AAAGGCCAGC AAAAGGCCAG	2520
GAACCGTAAA AAGGCCGCGT TGCTGGCGTT TTTCCATAGG CTCCGCCCCC CTGACGAGCA	2580
TCACAAAAAT CGACGCTCAA GTCAGAGGTG GCGAAACCCG ACAGGACTAT AAAGATACCA	2640
GGCGTTTCCC CCTGGAAGCT CCCTCGTGC CGTCTCCTGTT CCGACCCCTGC CGCTTACCGG	2700
ATACCTGTCC GCCTTCTCC CTTCGGAAG CGTGGCGCTT TCTCAATGCT CACGCTGTAG	2760
GTATCTCAGT TCGGTGTAGG TCGTTCGCTC CAAGCTGGC TGTGTGCACG AACCCCCCGT	2820
TCAGCCGAC CGCTGCGCCT TATCCGGTAA CTATCGTCTT GAGTCCAACC CGGTAAGACA	2880
CGACTTATCG CCACTGGCAG CAGCCACTGG TAACAGGATT AGCAGAGCGA GGTATGTAGG	2940
CGGTGCTACA GAGTTCTTGA AGTGGTGGCC TAACTACGGC TACACTAGAA GGACAGTATT	3000
TGGTATCTGC GCTCTGCTGA AGCCAGTTAC CTTCGGAAAA AGAGTTGGTA GCTCTTGATC	3060
CGGCAAACAA ACCACCGCTG GTAGCGGTGG TTTTTTGTT TGCAAGCAGC AGATTACGCG	3120
CAGAAAAAAA GGATCTCAAG AAGATCCTT GATCTTTCT ACAGGGTCTG ACGCTCAGTG	3180
GAACGAAAAC TCACGTTAAG GGATTTGGT CATGAGATTA TCAAAAAGGA TCTTCACCTA	3240
GATCCTTTA AATTAAAAAT GAAGTTTAA ATCAATCTAA AGTATATATG AGTAAACTTG	3300
GTCTGACAGT TACCAATGCT TAATCAGTGA GGCACCTATC TCAGCGATCT GTCTATTCG	3360
TTCATCCATA GTTGCCTGAC TCCCCGTCGT GTAGATAACT ACGATACGGG AGGGCTTACC	3420
ATCTGGCCCC AGTGTGCAA TGATACCGCG AGACCCACGC TCACCGGCTC CAGATTTATC	3480
AGCAATAAAC CAGCCAGCCG GAAGGGCCGA GCGCAGAAGT GGTCTGCAA CTTTATCCGC	3540
CTCCATCCAG TCTATTAATT GTTGCCTGGGA AGCTAGAGTA AGTAGTTCGC CAGTTAATAG	3600
TTTGCACAC GTTGTGCCA TTGCTGCAGG CATCGTGGTG TCACGCTCGT CGTTTGGTAT	3660
GGCTTCATTC AGCTCCGGTT CCCAACGATC AAGGCGAGTT ACATGATCCC CCATGTTGTG	3720
CAAAAAAGCG GTTAGCTCCT TCGGTCTCC GATCGTTGTC AGAAGTAAGT TGGCCGCAGT	3780
GTTATCACTC ATGGTTATGG CAGCACTGCA TAATTCTCTT ACTGTCATGC CATCCGTAAG	3840
ATGCTTTCT GTGACTGGTG AGTACTAAC CAAGTCATTC TGAGAATAGT GTATGCGGGCG	3900

ACCGAGTTGC TCTTGCCCCG CGTCAACACG GGATAATACC GCGCCACATA GCAGAACTTT	3960
AAAAGTGCCT ATCATTGGAA AACGTTCTTC GGGGCGAAAA CTCTCAAGGA TCTTACCGCT	4020
GTTGAGATCC AGTCGATGT AACCCACTCG TGCACCCAAC TGATCTTCAG CATCTTTAC	4080
TTTCACCAGC GTTTCTGGGT GAGCAAAAAC AGGAAGGCAA AATGCCGCAA AAAAGGGAAT	4140
AAGGGCGACA CGGAAATGTT GAATACTCAT ACTCTTCCTT TTTCAATATT ATTGAAGCAT	4200
TTATCAGGGT TATTGTCTCA TGAGCGGATA CATATTTGAA TGTATTTAGA AAAATAAACAA	4260
AATAGGGGTT CCCGCGCACAT TTCCCCGAAA AGTGCCACCT GACGTCTAAG AAACCATTAT	4320
TATCATGACA TTAACCTATA AAAATAGGCG TATCACGAGG CCCTTTCGTC TTCAAGAA	4378

## (2) INFORMATION FOR SEQ ID NO: 10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

AAAGACTCCG CGGGCGAAGT T

## (2) INFORMATION FOR SEQ ID NO: 11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

TTATCTAGAG TCGTTGGTCC AACCTTCATC

(2) INFORMATION FOR SEQ ID NO: 12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 4366 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: circular

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT	60
<u>TET C GENE START CODON</u>	
AGGGCCAGA TCTTAATCAT CCACAGGAGA CTTTCT <u>GATG</u> AAAAACCTTG ATTGTTGGGT	120
CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGGACAT	180
CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTATCA CATATCCAGA	240
TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACAA ACGAATCTTC	300
TGAAGTTATC GTGCACAAGG CCATGGACAT CGAATAAACAC GACATGTTCA ACAACTTCAC	360
CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC	420
TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG	480
<u>SacII</u>	
GTCTGTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG AAAGACTCCG CGGGCGAAGT	540
TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTCAAC GCGTACCTGG CTAACAAATG	600
GGTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT	660
TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC	720
TCTTAAGCTG GACC GTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAAACTG TATACCAGCT ACCTGTCTAT	840

CACCTTCCTG CGTGACTTCT GGGGTAACCC GCTGCGTTAC GACACCGAAT ATTACCTGAT	900
CCCGGTAGCT TCTAGCTCTA AAGACGTTCA GCTGAAAAAC ATCACTGACT ACATGTACCT	960
GACCAACGCG CCGTCCTACA CTAACGGTAA ACTGAACATC TACTACCGAC GTCTGTACAA	1020
CGGCCTGAAA TTCATCATCA AACGCTACAC TCCGAACAAC GAAATCGATT CTTTCGTTAA	1080
ATCTGGTGAC TTCATCAAAC TGTACGTTTC TTACAACAAC AACGAACACA TCGTTGGTTA	1140
CCCGAAAGAC GGTAACGCTT TCAACAAACCT GGACAGAATT CTGCGTGTG GTTACAACGC	1200
TCCGGGTATC CCGCTGTACA AAAAAATGGA AGCTGTTAAA CTGCGTGACC TGAAAACCTA	1260
CTCTGTTCACTGAACTGT ACGACGACAA AAACGCTTCT CTGGGCTGG TTGGTACCCA	1320
CAACGGTCAG ATCGGTAACG ACCCGAACCG TGACATCCTG ATCGCTTCTA ACTGGTACTT	1380
CAACCACCTG AAAGACAAAAA TCCTGGGTTG CGACTGGTAC TTCGTTCCGA CCGATGAAGG	1440
<u>XbaI S.Mansoni P28 GENE START</u>	
TTGGACCAAC GACTCTAGAA <u>TGGCTGGCGA</u> GCATATCAAG GTTATCTATT TTGACGGACG	1500
CGGACGTGCT GAATCGATTG GGATGACTCT TGTGGCAGCT GGTGTAGACT ACGAAGATGA	1560
GAGAATTAGT TTCCAAGATT GGCCAAAAAT CAAACCAACT ATTCCAGACG GACGATTGCC	1620
TGCAGTGAAA GTCACTGATG ATCATGGGCA CGTGAATGG ATGTTAGAGA GTTTGGCTAT	1680
TGCACGGTAT ATGGCGAAGA AACATCATAT GATGGGTGAA ACAGACGAGG AATACTATAG	1740
TGTTGAAAAG TTGATTGGTC ATGCTGAAGA TGTAGAACAT GAATATCACA AAACTTTGAT	1800
GAAGCCACAA GAAGAGAAAG AGAAGATAAC CAAAGAGATA TTGAACGGCA AAGTTCCAGT	1860
TCTTCTCAAT ATGATCTGCG AATCTCTGAA AGGGTCGACA GGAAAGCTGG CTGTTGGGGA	1920
CAAAGTAACT CTAGCTGATT TAGTCCTGAT TGCTGTCATT GATCATGTGA CTGATCTGGA	1980
TAAAGGATTCTAACTGGCA AGTATCCTGA GATCCATAAA CATCGAGAAA ATCTGTTAGC	2040
<u>STOP BamHI</u>	
CAGTTCACCG CGTTGGCGA AATATTTATC GAACAGGCCT GCAACTCCCT <u>TCTAAGGATC</u>	2100
CGCTAGCCCG CCTAATGAGC GGGTTTTTT TTCTCGGGCA GCGTTGGGTC CTGGCCACGG	2160
GTGCGCATGA TCGTGCTCCT GTCGTTGAGG ACCCGGCTAG GCTGGCGGGG TTGCCTTACT	2220
GGTTAGCAGA ATGAATCACC GATACGGAG CGAACGTGAA GCGACTGCTG CTGCAAAACG	2280
TCTGCGACCT GAGCAACAAAC ATGAATGGTC TTCGGTTCC GTGTTCGTA AAGTCTGGAA	2340
ACGGCGGAAGT CAGCGCTCTT CCGCTTCCTC GCTCACTGAC TCGCTGGCT CGGTCGTTCG	2400

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TTGCCCGGCG TCAACACGGG ATAATACCGC GCCACATAGC AGAACTTAA AAGTGCTCAT	3960
CATTGGAAAA CGTTCTTCGG GGGGAAACT CTCAAGGATC TTACCGCTGT TGAGATCCAG	4020

TTCGATGTAA CCCACTCGTG CACCCAAGT ATCTTCAGCA TCTTTACTT TCACCAGCGT	4080
TTCTGGGTGA GCAAAAACAG GAAGGCAAAA TGCCGCAAAA AAGGGAATAA GGGCGACACG	4140
GAAATGTTGA ATACTCATAAC TCTTCCTTTT TCAATATTAT TGAAGCATT ATCAGGGTTA	4200
TTGTCTCATG AGCGGATACA TATTTGAATG TATTTAGAAA AATAAACAAA TAGGGGTTCC	4260
GCGCACATTT CCCCGAAAAG TGCCACCTGA CGTCTAAGAA ACCATTATTA TCATGACATT	4220
AACCTATAAA AATAGGCGTA TCACGAGGCC CTTTCGTCTT CAAGAA	4366

CLAIMS

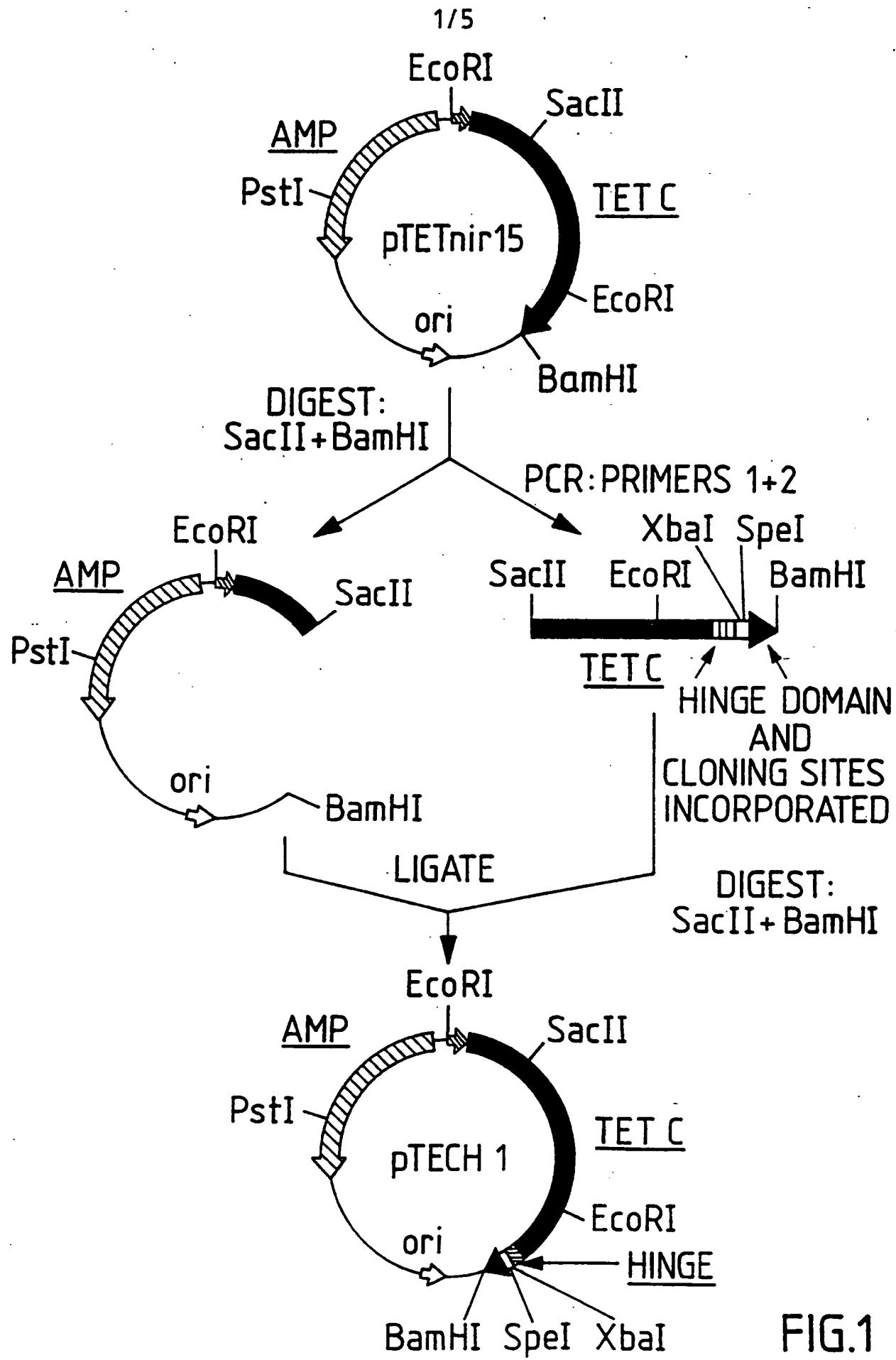
1. A DNA construct comprising a DNA sequence encoding a fusion protein of the formula TetC-(Z)<sub>a</sub>-Het, wherein TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein, Z is an amino acid, and a is zero or a positive integer, provided that (Z)<sub>a</sub> does not include the sequence Gly-Pro.
2. A DNA construct according to Claim 1 wherein (Z)<sub>a</sub> is a chain of 0 to 15 amino acids.
3. A DNA construct according to Claim 2 wherein (Z)<sub>a</sub> is a chain of less than 4 amino acids.
4. A DNA construct according to Claim 3 wherein (Z)<sub>a</sub> is a chain of two or three amino acids, the DNA sequence for which defines a restriction endonuclease cleavage site.
5. A DNA construct according to Claim 2 wherein a is zero.
6. A DNA construct according to Claim 2 in which (Z)<sub>a</sub> is free from glycine and/or proline.
7. A DNA construct according to any one of the preceding

Claims wherein the heterologous protein Het is an antigenic sequence derived from a virus, bacterium, fungus, yeast or parasite.

8. A DNA construct according to Claim 7 wherein the heterologous protein Het is the Schistosoma mansoni P28 glutathione S-transferase antigen.
9. A replicable expression vector, for example suitable for use in bacteria, containing a DNA construct as defined in any one of Claims 1 to 8.
10. A host, for example, a bacterium, having integrated into the chromosomal DNA thereof a DNA construct as defined in any one of Claims 1 to 8.
11. A fusion protein as defined in any one of Claims 1 to 8.
12. A process for the preparation of a bacterium (preferably an attenuated bacterium), which process comprises transforming a bacterium with a DNA construct as defined in any one of Claims 1 to 8.
13. A vaccine composition comprising a fusion protein, or an attenuated bacterium expressing said fusion protein, the fusion protein being as defined in any one of Claims 1 to 8; and a pharmaceutically

acceptable carrier.

14. A method of immunising a patient, e.g. a human patient, which comprises administering to the patient an effective immunising amount of a vaccine composition as defined in Claim 13.



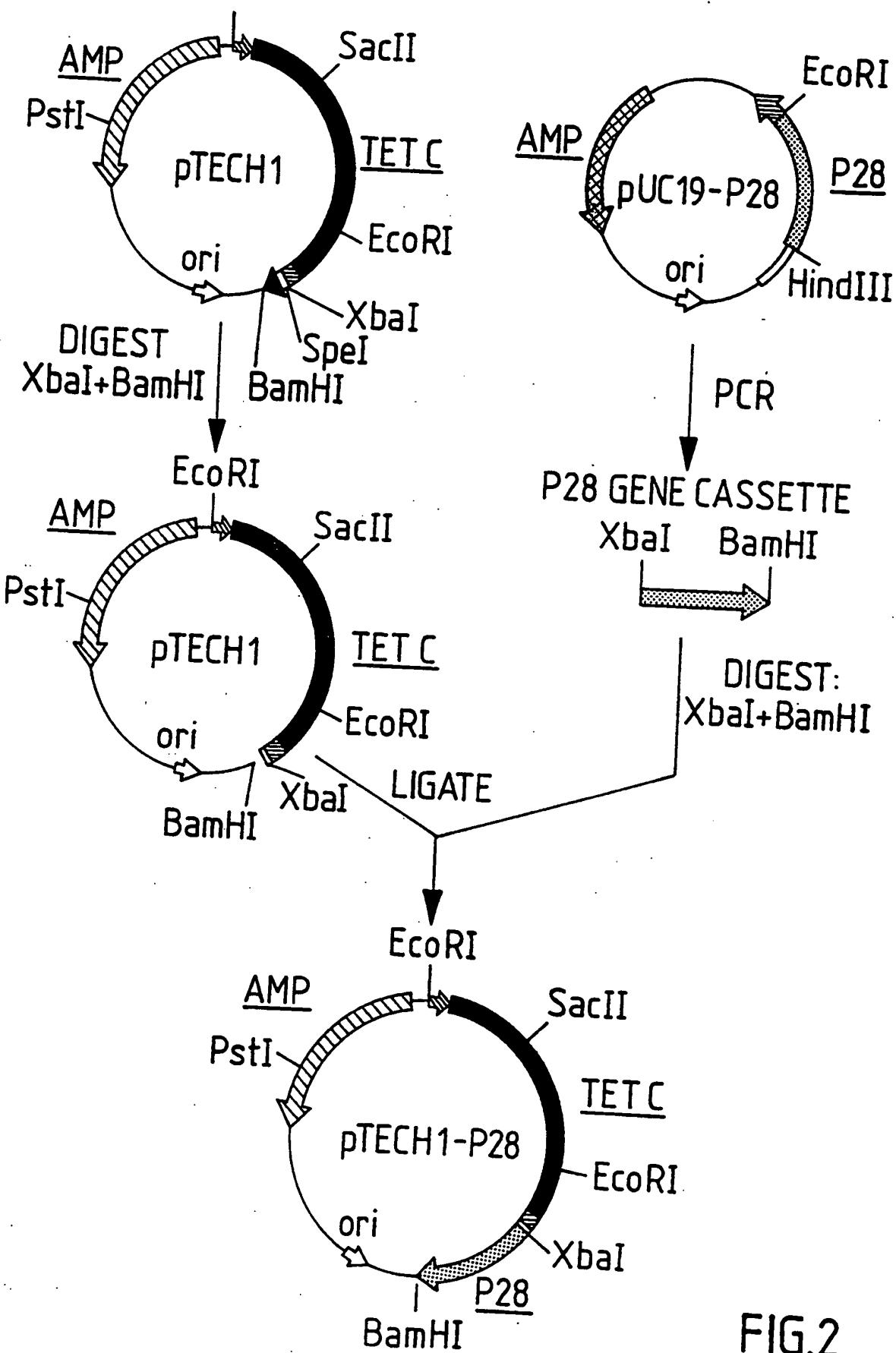


FIG.2

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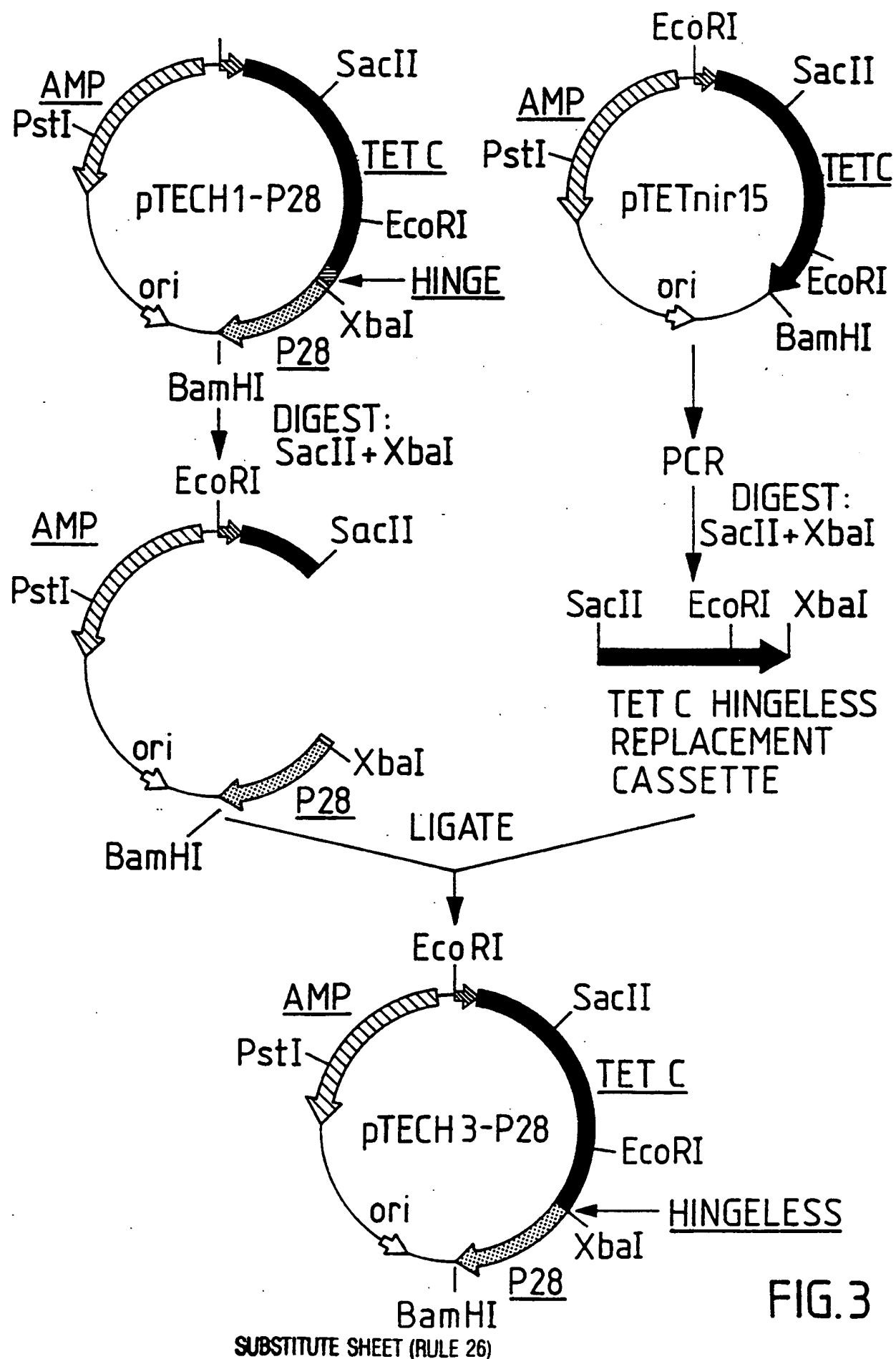
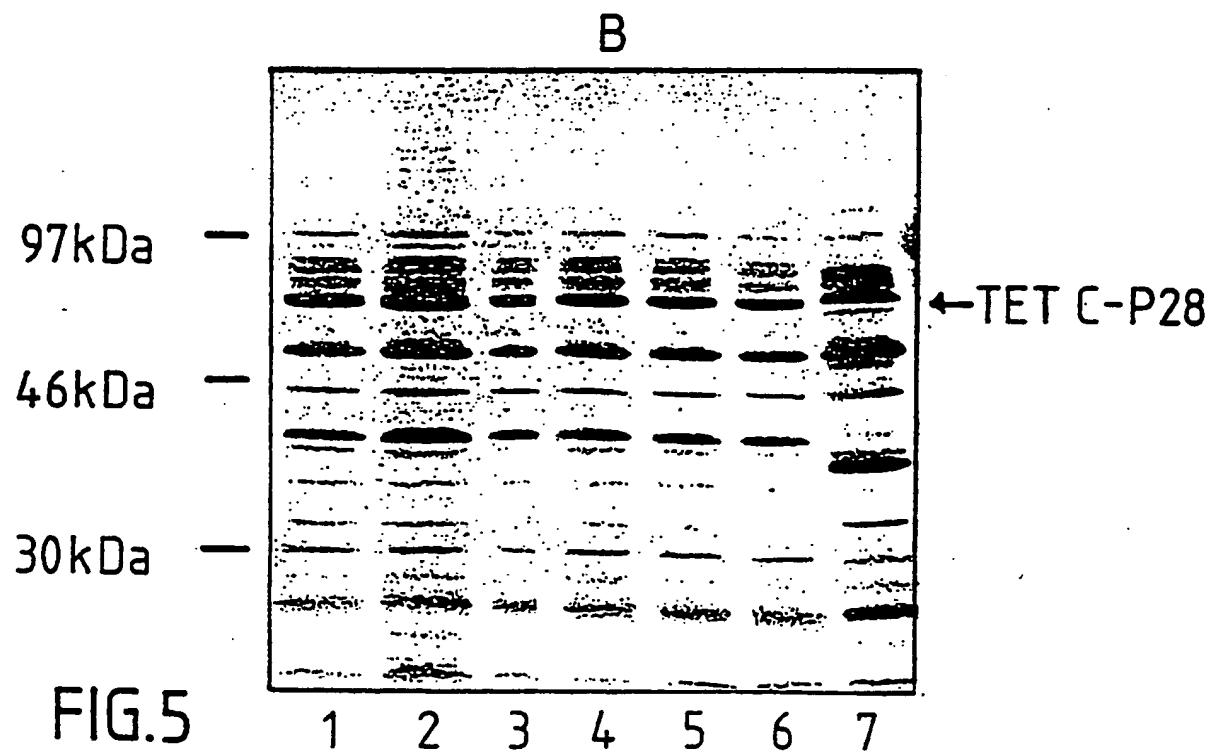
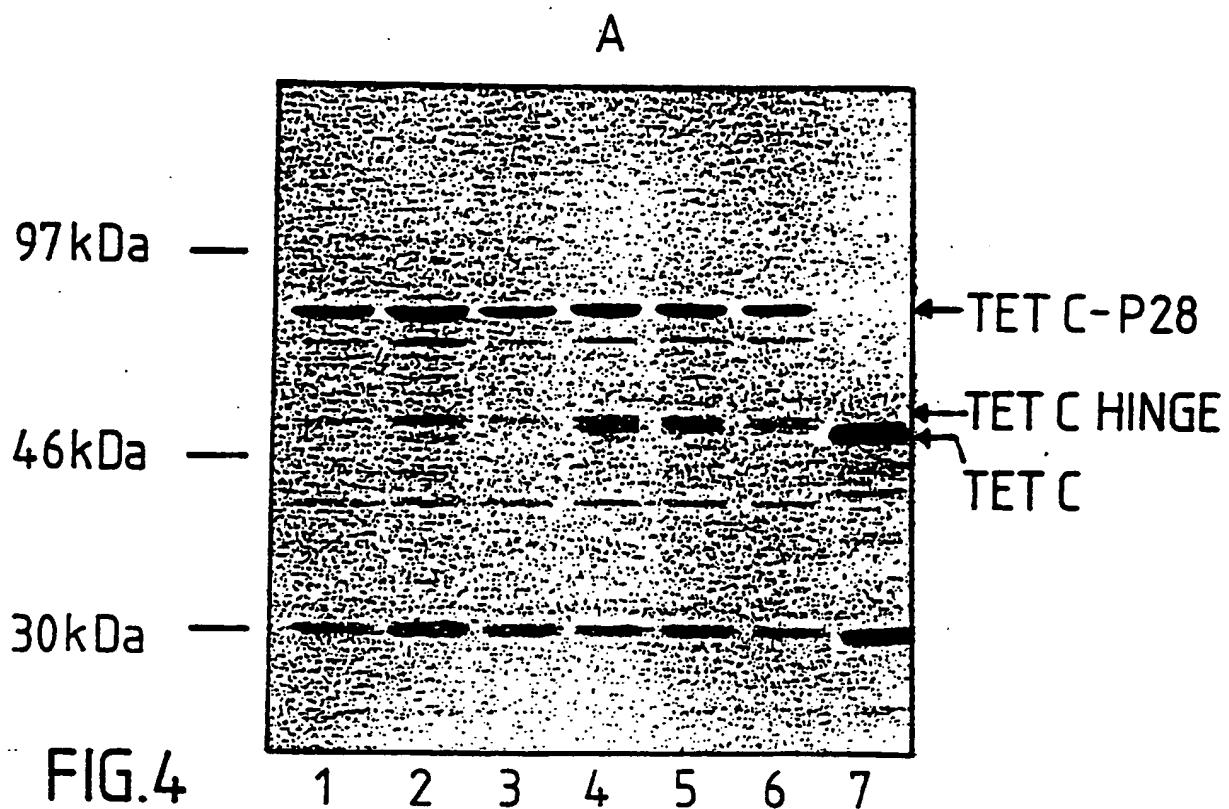


FIG. 3

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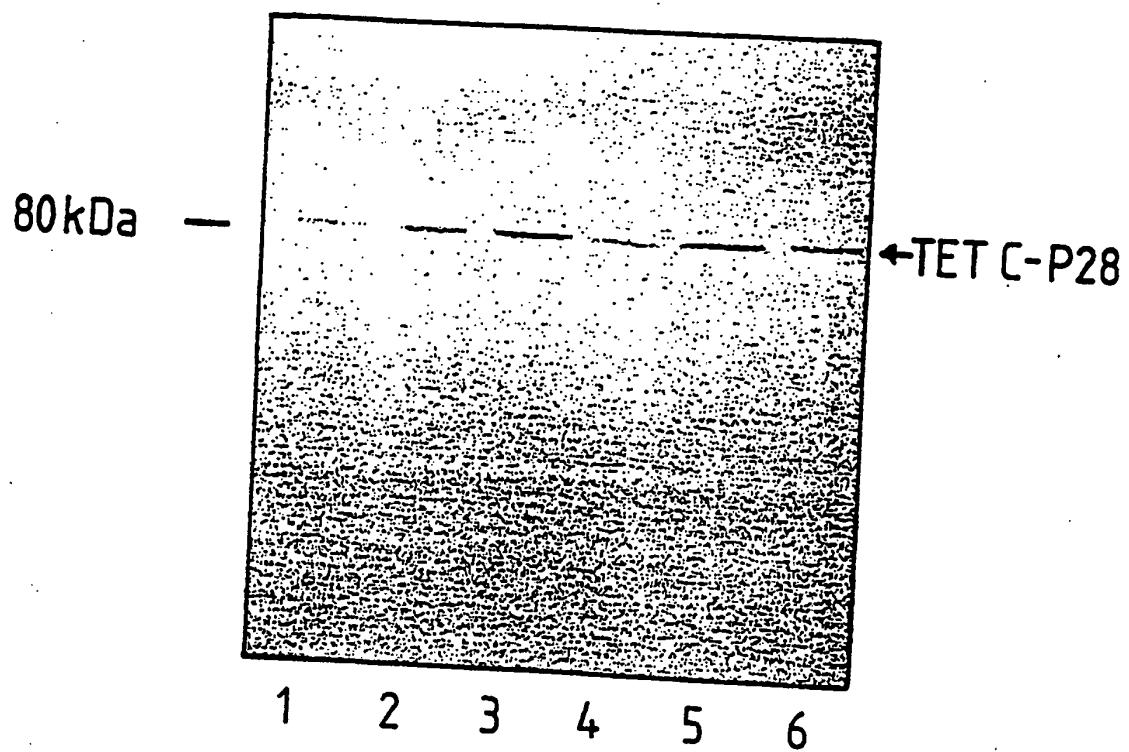


FIG.6

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